"Preliminary Note on the Anatomy of the Umbilical Cord"*. By Lawson Tait, F.R.C.S. &c. Communicated by W. S. Savory, F.R.S. Received April 28, 1875.

[Plates 11, 12, 13, 14.]

I. *Its external Form and Method of Growth.*

The peculiar twisted appearance of the human umbilical cord has received much attention from anatomists, and has been the subject of much ingenious speculation. According to Velpeau ('Embryologie') the torsion begins as early as the seventh or eighth week, whilst Burdach has not observed it earlier than the tenth. I have repeatedly seen fœtuses, apparently of the twelfth and thirteenth week, in which no appearance of twisting was observable in the cord, though one of the most perfectly twisted cords in my possession belongs to a fœtus of certainly not more than thirteen weeks' development.

Velpeau attributes the twisting simply to the rotation of the fœtus. Schroeder Van der Kolk supposes that the blood flowing in the arteries exerts a backstroke influence on the pelvis of the swimming fœtus, thus determining its revolution in one direction or the other, as the arteries are to be found to the right or left of the vein. In order to dismiss this view we have only to recollect that the umbilicus could not in any way become a fixed axis, and that the mechanical arrangement of the heart, in the non-separation of its streams, would yield but a very weak impulse until very late in pregnancy. The revolution of the fœtus is not known to occur, though its occurrence is probable. Such revolution occurs in the spawn of the frog as early as the first segmentation of the black sphere; but then it is evidently the result of the necessity there is for an equal exposure of all parts of the embryo to the action of light and heat, just as the germinal spot is always uppermost in the bird's egg. No such necessity exists in the persistently included mammalian ovum, and the revolution of the fœtus cannot be accepted. If it did occur it is highly improbable that the revolutions could number only from four to eighteen, these being the ranges I have noticed in a large number of fully developed cords. Another objection to Schroeder's hypothesis is that, as a matter of fact, the arteries leave the omphalic ring nearly always below the vein and symmetrically arranged in relation to it. Their passage to one or other side of it is seldom apparent till the external dermal ring has been reached. Also I have seen the first revolution of the arteries pass from right to left, after which they suddenly bent on themselves and passed up the cord in an irregularly straight course, whilst the vein maintained the normal spiral. Further, I have seen the arteries reverse their course about the middle of the cord, though the vein maintained the uniform spiral.

Sir James Simpson ('Edinburgh Medical Journal,' July 1859) was of

* See Proceedings, vol. xxiii. p. 498.

opinion that at the time of the commencement of the torsion the right iliac artery appears more like the continuance of the aorta than the left, the latter appearing more like a branch, the right having, therefore, a stronger blood-stream than the left; it would thus influence the fœtus. This supposition is ingenious; but I cannot find any fact which will support it. I have examined several fœtuses from the ninth to the sixteenth week without being able to discover any difference in the right and left iliac arteries. Such difference, if it exist, should continue during the growth of the cord; and I have entirely failed to find any evidence of it in any of the large number of fœtuses I have examined. Moreover, it seems greatly contradicted by the fact established by Hecker, that the twist is once to the left for 3·5 times to the right. Further, are we to suppose that in the cases of well-matured children in whose cords there are no twists, or only very slight ones, the embryo has continued perfectly still in the cavity of the amnion?

Neugebauer ('Morphologie der menschlichen Nabelschnur,' Breslau, 1858) explains the rotation by the pressure of the blood-stream on the walls of the vessels. The umbilical vein, he states, has a greater area than the two arteries together, and is more distended, the pressure diminishing its growth in length, whilst that of the arteries is uninterfered with, and the natural arrangement must be spiral. Whatever be the explanation, it is a fact which my injections and dissections have established beyond dispute, that the arteries have a greater length than the vein in very many cases, but it is not true in all.

In some cords the vein is longer than the arteries, for it remains spiral whilst they go almost straight. In others the vein continues persistently and regularly a definite spiral direction, whilst both arteries course over it first in one direction and then excentrically in another, sometimes even turning back over their first course and presenting a varicose appearance on the cord, to return again to their normal direction. Neugebauer states what is in strict accordance with my own experience, that irregular twistings are very common on the arteries but very rare on the vein. I have never seen one on the vein.

Neugebauer further believes that the reason the majority of cords are twisted from right to left lies exclusively in a dissimilarity in the size of the arteries. He has found (in agreement with Simpson) that the right artery is larger than the left. Occasionally, he states, the left is the larger of the two, and then the twist is reversed.

Hyrtl ('Lehrbuch der Anatomie des Menschen') states that the left artery is usually the larger of the two. I do not see, in the writings of either of these two authorities, any details of the method of examination of their specimens.

My own method has been to remove the whole thickness of the abdominal wall from the base of the bladder up to and including the omphalic ring, along with a piece of cord. This I place in my freezing-

machine, and cut from it a number of consecutive sections, examining at intervals, by careful measurements, the two arteries. I have seen no reason to agree with the conclusions of Simpson and Neugebauer. Even if their position were established it could only refer to the contracted condition of the vessels after death, and this would afford no accurate clue to their relative sizes during life. But even if it did it would not explain, as I shall try to show, the spiral growth of the cord.

In the investigation of this subject my first endeavour was to ascertain which of the three tubes in the cord had the greatest influence in maintaining the spiral, either before the cord was separated from its connexions or after. If, while the cord was still attached to both mother and child, I passed a needle through the cord close to the child, so as to isolate the vein, and then compressed it against the needle, I found that the spiral was completely maintained. On the contrary, if I compressed the arteries and cord together towards the placenta, the cord emptied and became flaccid, losing its spiral appearance. This was the case very markedly in the instance of a cord which is the most perfectly spiral in my possession. On distention by injection it showed a complete helix in the remarkably short distance of an inch and an eighth with a perfect lumen through the helix of three sixteenths in diameter. In this cord the arteries coiled together within the helix of the vein. In no cord which I have injected, and in which the twist was evident at all, has it not been as evident that the vein was the main factor in the twist. I have established this by distending, in a well-twisted cord, the three vessels alternately with water. Distention of the vein induces the complete spiral of the cord. Distention of one artery has little or no effect, and distention of both arteries in no case equalled the results obtained by distending the vein. I have injected both arteries with some slightly resisting material, as stiff size, and after it has set I have distended the vein with plaster of Paris, and in every case it has become evident that the chief spirality lies in the vein. Injection of an artery with plaster of Paris and allowing the whole cord to dry seldom produces a well-marked spiral in any part of the cord, and never throughout its whole length. A similar proceeding with the vein will produce a perfect spiral throughout the whole length of any cord which has the twist running through it.

Neugebauer also found that blowing up the vein produced more marked twisting of the cord than blowing up the arteries. In one of my specimens injection with plaster has done so over a length of three feet, and the dried arteries are seen coiling round it; yet distention of these arteries by water did not produce any spiral at all. In any regularly spiral cord the arteries will always be found on injection to be within the helix, a point which is very suggestive that the vein is the chief factor in the production of the twist. In such cords as those in which the whole development and the spiral are evidently deficient (and this

has no relation whatever to the development of the child), the arteries are to be seen on the outside of the imperfect helix, and this greater length has to be accommodated by twistings and reversions. But even in such a cord sections are to be seen where the spiral becomes complete, and then the arteries take their normal place within the helix.

Injection of one or both arteries by plaster, with subsequent drying, does not produce a spiral even in cases where the cord has shown a very marked spiral when the vein has been previously distended with water.

When the spiral is faintly marked but the cord long, and the arteries not very much, if at all, longer than the vein, the spiral will be found always at the end near the fœtus. Thus in one specimen, which is very typical of this class, there are three well-marked helices occupying the six inches of the cord at the fœtal end. One artery was successfully injected, and it is seen to occupy an almost straight course in the middle of the helices, the uninjected artery accompanying it closely, whilst further on they are both seen to follow, with only one reversion or doubling, the almost straight course of the vein.

This last fact makes it very evident that the growth of the spiral is directed by some mechanism at the fœtal end of the cord, and not by any hypothetical revolutions of the fœtus.

From the appearances of some cords it would also seem as if the spiral growth of the cord became interrupted for a short time, or even reversed, and then that it resumed its original direction.

In the first and fourth volumes of the 'Encyclopædia of Anatomy' some interesting quotations are given by Vrolik and Mr. J. Hart. Vrolik gives some cases where the vessels ran from the fœtus to the placenta separately, and not twisted in a cord. He also mentions that extreme shortness of the cord is generally accompanied by ectopia of the abdominal viscera, indicating an arrest of development at an early period of embryogenesis. Rudolphi states that the umbilical vein is persistently double in the Quadrumana of the new world; but I cannot anywhere find a statement as to whether, in such a case, the cord is twisted or not.

I think we may conclude from some of these facts that both the growth of the cord and its spiral direction are due to some mechanism at the omphalic ring, and that probably that mechanism is in a most immediate relation to the umbilical vein.

Further, I think it certain that the greater part of the spiral, and the closest coils of the spiral, are formed during the later months, or even weeks, of gestation. Thus in cords which are deficient in the spiral it is always most marked near the fœtus; and in one which I have already alluded to as the most perfectly spiral cord I have seen, the helices were complete in an inch and an eighth near the child, whilst they gradually opened out towards the placenta, so that the last was nearly three inches

in length. This could not be the case if the twisting were due to the rotation of the fœtus during early embryonic life, as then we should expect that the spiral would be uniformly spread over the cord, if, indeed, it would not be most marked near the placenta. Neugebauer says that the spirals have a uniform length, with the exception of those close to the placenta, which are almost invariably longer.

In his 'Cellular Pathology,' Professor Virchow gives a drawing of the umbilical cord, and the following description of its vessels:—"The only capillary vessels which are found in the whole length of the umbilical cord of a somewhat developed fœtus do not extend more than about 4 or 5 lines (in rare instances a little further) beyond the abdominal walls into that part of the cord which remains after birth. The further up this vascular part extends the greater the development of the navel. When the vascular layer is prolonged but a very short distance the navel is depressed. The capillaries mark the limits of the permanent tissue; the deciduous portion of the cord has no vessels of its own."

I have made many very careful injections of fœtuses of various ages in order to verify this observation. For a long time I was quite unable to do so, and I had the impression that Virchow had mistaken a part of the dermal ring, with the epithelium rubbed off, for a part of the true substance of the cord. From a large number of observations I have found that the dermal ring runs on to the cord in a camb-like shape (Plate 11. fig. 1)—that is, that the length of the ring is unequal all round, the greatest length corresponding generally to the position of the vein at the upper part of the ring (Plate 11. fig. 2). This, however, is not constant. At this point the capillary plexus is shown in Virchow's drawing; and from a completion of Virchow's partial observation, it seems to me that in this arrangement we have the immediate mechanism of the spiral growth of the cord.

The necessities which have evolved it are probably those of the erect position of the human animal, by which the fœtus, resting on the brim of the pelvis, might compress the cord to an unsafe extent. This compression would be better resisted by a spiral cord than by a straight one. Further, the form of the human uterus, and the occurrence of single gestation as a rule, favour movements of the fœtus in all directions; so that it is well known to the tocologist that the fœtus frequently changes its position, though nothing like revolutions are known. During these movements, however, the child might make one or more revolutions, and these might have a disastrous result if the cord were straight; but it being already twisted, a few revolutions in the direction of the twist could do no harm in the way of occluding the vessels, nor could a few revolutions in the direction of untwisting it be at all likely to be hurtful.

John Goodsir has shown how thoroughly the spiral runs through all

growth, and how perfectly it is seen in joints. It is the universal direction of growth in plants and shells, and may yet be shown to exist in structures where little suspected. If we accept the doctrine of continuous descent, we can be at no loss to account for the presence of a spiral in the umbilical cord, the most lowly organized structure in the human economy. If we do not accept that doctrine as more than an hypothesis, the spiral growth of the cord may yet be advanced as an argument in favour of its establishment. To this end its history must be carefully worked out, and to this I hope to be able to make a contribution in another note.

Virchow is the only author whom I have found to state that capillaries pass from the structures of the child into the substance of the cord; but there can be no doubt that he is correct.

I injected a large and fully developed still-born child with a strong solution of Berlin blue in size, under the pressure of 350 millims. of mercury. Every organ was completely injected and the liver had given way.

At the fœtal attachment of the cord, and running upwards from the line of demarcation, was an arrangement of small capillaries. These were visible all round the attachment of the cord, but at some parts were not more than a millimetre in length, while elsewhere they were 8 or 10 millims. They did not seem to form loops, but to run straight out from the dermal ring along the cord and immediately under its surface.

There were five points at which the exaggeration in length was very marked, three of these corresponding to the region of the vein, and one to each of the arteries (Plate 11. fig. 2).

It will be seen from this that the nutrition and growth of the cord, supposing them to be in part due to this arrangement of blood-vessels, must be unequal—that is, that one side will grow somewhat more than that opposite. This, of course, is certain to result in a spiral; and this principle of unequal nutrition I hope to be able to demonstrate in further communications as a great principle in all organic spiral growth.

A further consideration of the arrangement and function of this plexus is given in another division of this note.

II. *Its Covering.*

The naked-eye appearance of the covering of the umbilical cord needs no minute description here. Like all other serous surfaces, it is smooth and glistening, and it is continuous with the epithelium of the amniotic surface of the placenta; but a very sharp line of demarcation exists between the epithelial surface of the cord and that of the skin covering the omphalic canal.

This line, however, is only a naked-eye appearance; for staining and examination by the microscope show that the layers are continuous.

I have not seen any difference between the structure of the two

epithelial surfaces, nor do I think that there is much difference in their function.

The epithelial covering of the cord is said to be derived from the amnion; but this is a loose method of description which has yet to be substantiated.

In all the microscopic examinations from which descriptions are taken in this paper, the sections have been made by my freezing section cutter, from fresh tissue unless otherwise stated; and they have been submitted to various staining-processes by the action of litmus, hæmatoxylin, red cabbage, &c., as described in Humphrey and Turner's 'Journal of Anatomy and Physiology,' May 1875. The lenses used have been a half-inch and a quarter-inch objectives of Natchet, with the corresponding eyepieces 1, 2, and 3, and an immersion sixteenth of Hartnack.

To obtain pieces of the epithelial surface of the fresh cord of any size and of sufficient thinness to see the surface transparently was a matter of considerable difficulty. I first of all tried freezing the fresh cord while pressed flat against a piece of glass, tearing off the glass and then cutting off the flattened surface. To the fact that the glass removed with it a great part of the epithelium I owe a most important though accidental observation. I further found that first smearing the glass with glycerine prevented the cord becoming intimately attached to it; and by carefully washing off the glycerine by distilled water I obtained a perfect epithelial surface free from disturbance. This I examined after being treated in various ways. Soaking the section in an ammoniated solution of litmus or hæmatoxylin and reducing the colour by washing it in a ·004 per cent. solution of nitric acid, I found that the epithelial layer was single and composed of irregularly polygonal cells, regularly nucleated. These cells were bedded in a fibrillar matrix, very thin, and in which no special structure could be discovered, and which is certainly only a slightly condensed arrangement of the canalicular system on which the cells lie. Virchow has described the subepithelial tissue as a "somewhat denser dermoid layer;" but I have failed to see any such analogy. The fusiform nuclei of the canalicular tissue are to be seen (Plate 11. fig. 6) immediately under the single layer of epithelium, lying in the direction of the long axis of the cord. These epithelial cells differ from similar cells on the fœtal surface of the placenta and amnion only in being somewhat less regular in size and arrangement; and, indeed, in these points they differ to a considerable extent on various parts of the cord itself, for they are slightly larger and more regular near the fœtus than near the placenta. That there is only a single layer of cells is a point on which I am satisfied; for I have stained the whole layer removed on the glass, as I described above, and I have never been able to focus one cell above another.

Further, in a microscopic section of a fresh cord stained with hæmatoxylin the epithelial covering may be seen to be turned over. The

nuclei are stained; and when they are brought into focus under a quarter objective, it requires only about the thirtieth part of a revolution of a fine screw adjustment to bring the subjacent fusiform nuclei into clear definition, that screw having 56 threads to the inch. The thickness of the layer is therefore certainly not more than $\frac{1}{1700}$ of an inch.

For the silver treatment I have employed a solution of lactate of silver with the addition of some free lactic acid, and I have found the results more definite than those given by the employment of a solution of the nitrate. The method is advised by Serge Alferow, of Charkow. This treatment displays an irregularity of size and arrangement of the cells such as I do not see in those of any other epithelial surface, and which I think must be due to the singleness of the layer. It is not due to my method of treatment, for I have seen it in small pieces which I have snipped off by scissors, without freezing on glass. The intercellular substance takes on the characteristic brown colour (Plate 11. fig. 3), and between certain cells slight ganglioniform enlargements of this colour are to be seen in great numbers—the stomata spuria of Klein. I am in as great doubt as that author whether these dark spots have any thing to do with the subjacent canal-system. They may have ; but I have seen nothing as yet which convinces me that they are other than mere extensions of the peculiar intercellular substance which first takes up the argentic stain. That this stain is more than a mere filling up by the darkened solution of intercellular gutters must be the conviction of any one who works to any large extent with silver fluids ; for in other tissues it may be seen to affect nuclei with avidity, as notably, in my own experience, it does in the placenta and in the ovary. Certain groups of cells in epithelial surfaces are seen to take up this colour without apparent meaning ; but this is much less frequent in the cord than in the amnion, &c.

The groups of small darkly coloured cells or nuclei which are now admitted to mark the stomata of serous membranes are numerous on the cord; but I am bound to state that my experience of them had to be extended to other membranes before I could admit for them the interpretation which they had in the opinion of others, and notably of Koster. They are unquestionably the orifices of the vast system of canals which forms the basis of the cord and upon which it solely depends for its nutrition. Round their orifices, or within their entrance (I have not yet decided which), are to be seen these small darkly shaded cells. I doubt if they are endothelia. I believe that rather they are young epithelia in growth; that, in fact, these stomata are the points of growth and extension of the epithelial layer of the cord, and that the groups of darkly coloured cells of larger size to which I have already referred are the same in further progress. It certainly is the fact that round the stomata the uncoloured cells are often of much smaller size than they are at a little distance away. At a few points I have been fortunate enough to see these stomata leading directly into a canal, into which the

staining-fluid seemed to have permeated, and therefore rendered it distinct.

But the absolute proof is to be found in a few preparations where the epithelium has been partly removed by the accident I have already described. Thus at one spot I saw the edge of the coloured epithelium curled up, displaying the naked (Plate 11. fig. 3) canals where it had been removed; and there the stomata could be seen leading directly into the canals where the epithelium was still *in situ*. The canals will be seen branched in all directions, with large central spaces. At one point at least I certainly saw such an enlargement correspond exactly with a true stoma; and though much remains to be done in this direction, it seems to me more than likely that each of these lacunar enlargements may be at any or at some time the site of a stoma.

The number of stomata on the surface of the cord is certainly very much less than the number of lacunar enlargements in the subjacent canals. But it does not seem probable that the sites of the stomata are constant. They seem rather to be in process of change, formed by loss of epithelium and closed by its regeneration. This is not much more than speculation; but it would explain some curious facts hitherto not explicable.

I have already mentioned that there seems to be some difference in the details of the arrangement of the epithelium at the fœtal end of the cord from that at the placental end. Perhaps these differences are accidental to the one cord examined for this purpose; but even there they are marked enough to be mentioned. The cells are smaller and more irregularly jointed, and more especially they seem elongated in the direction of the long axis of the cord. They are not so well marked nor so numerous, and the darkened groups of small cells are not much seen. The whole structure gives the impression as if it was older than that nearer the fœtus. Thus in the canals and in the stomata are to be seen regular rows of minute refracting globules, visible only under very high powers, the nature of which I have been unable to make out as they are seen only after deep silver staining.

III. *Its Substance.*

Since the publication of Wharton's 'Adenographia' (London, 1656), the name of "Wharton's jelly" has been retained for the proper substance of the cord.

Although the substance is in no sense gelatinous, the name is convenient from its traditions, and it is likely to be retained. The jelly-like appearance is due simply to a preponderance of fluid contained in alveoli. Virchow dismisses the chemical character of this fluid by saying that it contains mucin. So far as I have gone, however, it contains much more definite compounds, and seems closely to resemble the liquor amnii, if, indeed, it be not that fluid itself. This point requires much more inves-

tigation than I have yet been able to give to it. Virchow regards this tissue as ranking with embryonic subcutaneous tissue and the vitreous humour. I am not yet in a position to give an opinion on this relationship, though I think it possible.

This alveolated tissue is divided, throughout the whole length of the cord, into three columns, one of which surrounds each blood-vessel. The divisions between these three columns are not visible to the naked eye, but they become very perceptible when the tissue is injected in the manner to be immediately described. When the nozzle of the injecting-apparatus is inserted into the tissue of one column, the fluid will be found to travel along that district only, unless such pressure is used as produces rupture of the limitation of the column. The injection will be found to surround the blood-vessel of its district with great uniformity (as shown in Plate 11. fig. 4), but the injection will never be found to encroach upon the walls of the vessel. The limitation can scarcely be said to be membranous; for if the adjacent tissue of two columns be injected, the line of demarcation where they touch cannot be made out. It seems to depend upon the absence of communication between the canals of the two columns. This is a most interesting fact bearing on the nutrition of the blood-vessels.

Virchow describes the proper substance of the cord as consisting of "reticulated tissue, the meshes of which contain mucin and a few roundish cells, whilst its trabeculæ are composed of a striated fibrous substance in which lie stellate corpuscles. When a good preparation has been obtained by treatment with acetic acid, a symmetrical network of cells is brought to view, which splits up the mass into regular divisions."

Kölliker considers the substance to be "immature connective tissue with stellate anastomosing cells." Weisemann thinks "it corresponds to the skin and subcutaneous tissue in arrest of development." But it seems to me, however probable their explanations of the biological relations of the tissue may be, that their descriptions of its anatomy are only partially accurate and far from being complete. The facts are that the striated fibrous tissue is composed of the collapsed walls of numerous canals of which alone the proper tissue of the cord is made up. When only partially emptied some of them appear like stellate cells, and therefore they give the deceptive appearance of there being a matrix in which Virchow's "connective-tissue corpuscles" are imbedded. In the lacunar spaces of the system oval nuclei are imbedded in the walls of the canals. In a large number of observations I have never seen these nuclei alter their shape and position.

Before detailing the results of my observations on these canals, it will prove more satisfactory if I describe my methods of preparing the specimens observed. First of all I may say that I have in no instance drawn a conclusion from observations made on a cord otherwise than perfectly fresh, unless it is distinctly stated to the contrary. I have found the

examination and treatment of tissue which has been subjected to hardening reagents so unsatisfactory that I have quite discarded it.

All my sections are made by the freezing process (described in Humphrey and Turner's Journal for May 1875), so that sections of the perfectly fresh cord of about $\frac{1}{600}$ of an inch in thickness have been examined. These have been subjected to various treatments—as simple clearing by glycerine, destruction by acetic acid, staining by silver lactate, and by my various indifferent staining-fluids, hæmatoxylin, litmus, cabbage, &c. (also described in Humphrey and Turner's Journal).

My injecting-apparatus is so arranged that it acts automatically when set at work. The tissue injected and the whole apparatus is surrounded by a current of warm water, the temperature of which is registered. The injecting force is supplied by compressed air admitted directly to the surface of the injecting-fluid, and the pressure is registered by a manometer. The nozzles used vary in diameter from 1 to 4 millims. The fluid used is a ten-per-cent. mixture of Seitels's Berlin blue suspended in firm size. This does not stain the tissue because it is not in solution, yet its granules are too small to be seen by any power of lens in my possession. That it is not in solution is certain from the fact that it is completely removed from the fluid by adding some albumen and boiling. Similar but not so satisfactory results may be obtained by Davies's granular carmine; but here the granules are too large to enter the canals, save under such pressure as produces frequent extravasation.

One disadvantage of the Berlin blue is that it contains a little free acid, and must do so to remain visible. After a short time this acid destroys the colouring of the stained nuclei; so that, save in an almost perfectly fresh specimen, it is impossible to demonstrate the relations of the nuclei to the canals when distended by the injection.

The method of injection of these canals is apparently very rough. It consists simply in inserting a small nozzle superficially into the substance of the cord over and parallel with the course of a vessel, tying it in, and injecting under a low pressure of 50 or 60 millims. of mercury.

Schweiger-Seidel made the very obvious objection to this (Recklinghausen's) method that any appearances presented by it would be simply those of extravasation. Such was my own belief when I first tried it on the cord; but very short experience showed me that the result was a regular and uniform injection of a system of canals, and that extravasation was very rare and always limited to the immediate neighbourhood of the wound in the cord. With the whole apparatus at a temperature of 47° and a pressure of 60 millims., I have injected a column of the cord for a distance of 9 inches in about half an hour. The injection travels rather more rapidly in the direction from the child to the placenta than in the opposite direction.

I have repeatedly seen minute streams of the blue injecting fluid flowing from the surface of the cord into the water surrounding it, even

at as low a pressure as 55 millims., with a nozzle only 1 millim. in diameter; yet at a pressure of 350 millims. I have not produced a rent in the surface of the cord, though I have produced numerous extravasations into the alveoli and into the neighbouring columns. The appearances when these canals are distended are well shown in several of the drawings, but especially in Plate 11. figs. 5, 6, and Plate 12. fig. 14, in the first of which they are seen to run up close to the muscular coat of the artery. Transverse and longitudinal sections of the same piece of the cord show that they are stellate in every plane, and that they intercommunicate in every direction; but their processes are slightly longer in the long axis of the cord than in any other. This, however, is not constantly evident.

Recklinghausen regards these canals as wall-less spaces between the anastomosing cells, simple interspaces in the connective-tissue basis substance ("Ausgrabungen in der Bindegewebs-Grundsubstanz"); but that this is not so my own observations, substantiating those of Koster, I think completely established. It is best proved by preparations of the termination of the injected district, where the blue colour may be seen running into the processes of the so-called stellate "connective-tissue corpuscles," contrasting with the complete occupation by the colour of every thing but the alveoli*. It is in these alveoli exclusively that I have found the round migratory cells.

Henle thinks that the anastomosing cells may be the foundation plan for blood-vessels ("Gefässanlage"), such as are seen in the umbilical cords of all mammals but man. So far, however, as I have yet seen the vessels which extend over the mammalian cord are chiefly on its surface, as I have already mentioned they are to a limited extent at the fœtal insertion of the human cord; but this point is one for further research. It is scarcely possible, however, to regard a system of canals which constitutes *the whole tissue of the cord* as a representative of blood-vessels, otherwise it must somewhere be seen as an almost erectile tissue.

Fohmann has asserted that he has injected a complete system of lymphatic vessels in the cord by quicksilver; and though Virchow thinks that his material has permeated the alveoli, and Hyrtl that his lymphatics are mere chasms in the tissue, I think it possible that he really has injected these canals, but that from his inability to make sections which would retain the quicksilver in the tissue, he has not demonstrated the facts of his system. This difficulty is obviated by the use of size and Berlin blue.

Staining with silver lactate (1 in 800, with slight excess of lactic acid) leaves the canals as clear white spaces (Plate 11. fig. 3), but gives a decided brown edge to them, which shows that they are walled. Their general appearance after this treatment closely corresponds to that seen after

* This is also shown in silver-stained sections (Plate 11. fig. 3), where the walls seem indicated by an increase of colour.

their injection minus the extreme distention. I have never seen any appearance of endothelia in these canals; but there is a very constant relation of nuclei to their walls in the lacunar spaces. These nuclei, when examined by a power of 200 diameters, seem to be fusiform (Plate 11. fig. 8); but when examined by a sixteenth immersion-lens, they are found to be of a regular oval shape, and to have a nucleolus which is very small in proportion to the mass of protoplasm (Plate 11. fig. 7). They are not always solitary, and occasionally one large nucleus may be seen associated with a number of smaller structures which seem identical. These nuclei are readily shown by acetic acid; but by such treatment their relations to the lacunæ are destroyed. They readily take up the colouring-matter of an indifferent solution of hæmatoxylin; but I have not yet been able to colour them with litmus. These nuclei are constant.

In the alveoli, which lie between the anastomosing branches and also between the lacunæ of the canals, are sometimes found numbers of round cells. They do not readily take up hæmatoxylin, at least I have not often been enabled to find them by means of that stain, but they readily absorb the litmus colour. When examined by a quarter they appear like round free nuclei; but if examined very carefully, or with a sixteenth, they are seen to have a thin layer of uncoloured protoplasm round them. They are in fact cells (or nuclei) in which the nucleus (or nucleolus) is disproportionately large for its envelope: they are not constant. In some cords, especially when removed from large children, they are found very scantily; whilst in the cord of a small eight months' child (Plate 12. fig. 9) I found them to be extremely abundant. They are also, as in this instance, found far more numerous in some parts of the cord than in others, and in one district of the cord than in another. They are most abundant close to the umbilicus, and in the districts in which the capillaries are seen. They are certainly free in the alveoli; for I have seen them wandering and exhibiting amœboid movements on the warm stage, after having taken up the litmus colour. I have never seen the lacunar nuclei exhibit any movements, nor have I ever seen any appearance as if they multiplied by division. These round cells may not be confined to the alveoli, however, as they seem scattered over the tissue in the uninjected cord. In the injected cord I have seen them in the alveoli only. In sections taken near the umbilicus they are seen to be most numerous in the vicinity of a small capillary which ran up the cord certainly to as far as half an inch from the ring. Here they are also seen to be of larger size than elsewhere (Plate 12. fig. 11), and to appear close to the mass of blood-corpuscles which, as a clot, occlude this capillary. My inference is that they originate in this neighbourhood (to be afterwards more carefully described) and migrate throughout the cord. They do not ever appear as if they multiplied by division. The walls of this small vessel had no muscular fibre, but seemed to be formed merely by a condensation of the canalicular tissue.

Koster regards these two forms of cells as the same, and differing only in position. But he has evidently neither applied high powers nor delicate stains to them, so as to discover the presence of a nucleolus in one and its absence in the other. The different actions on them of litmus and hæmatoxylin seem very decisive as to their being different structures, and probably having different functions. They are also quite different in size and appearance.

Koster states that he has seen the nuclei of the lacunæ send fine shoots into the branching canals. This is only an optical delusion, which is dispelled by the use of the high power immersion-lens.

I conclude, therefore, that the proper tissue of the cord is entirely canalicular. How the canals are formed, and what relation their nuclei have to their growth and nutrition, has yet to be determined. It is, of course, more than probable that the explanation of the growth of the stellate corpuscles advanced by Virchow, Aeby, and Eberth is applicable to the lacunar canals; that is, that they are the result of cell modification, the body of the corpuscle expanding into a membrane for the formation of the lacuna and its processes, whilst the nucleus remains for nutritive reproduction. This, however, I am not yet prepared to accept, but it might explain one function of the round cells.

Koster speaks of having seen "in silver-stained sections irregular or interrupted lines showing through the white canals, which remind us of the luting substance between two epithelial cells;" but I have not been fortunate enough to have seen any of these lines.

I agree with Koster that it is probable that the canals communicate directly with the amniotic cavity by means of the stomata; but, beyond having satisfied myself that the stomata lead directly into the layer of canals immediately under the epithelium, I cannot say I have traced the continuity. I believe the minute streams of injection-fluid, which both Koster and I have seen flowing from the surface of the injected cord, have come from the stomata, but I have not yet caught the fact in a section. Koster makes a similar confession.

In one point I am in disagreement with all observers with whose work I am acquainted, in that I am certain that the nuclei of the lacunæ are not loose in the cavities but are adherent to the wall at one point. The double method of injection and staining proves this conclusively.

By no kind of process which I have employed, in quite a large number of observations, have I been able to discover any thing in the least degree resembling a nerve-fibre in the substance of the cord; and I have failed to substantiate Kölliker's observation of the entrance into it of branches from the hepatic plexus.

When one of the columns of the cord is injected the canals will be seen, as I have already said, to run up to the muscular walls of the blood-vessel of the column, but I have never seen a canal enter the muscular tissue.

It is then quite easy to discriminate between the canalicular and muscular tissue; but in the unprepared, or in the stained section, it is impossible to decide where exactly the muscular fibre begins, especially if the blood-vessel has been distended, for then the layers of canalicular tissue immediately outside the blood-vessel are stretched so as to be parallel in direction to the general course of the muscular fibres. It will be seen, therefore, that the whole column of the cord constitutes the external coat of the blood-vessel, and also the substitute for the *vasa vasorum* which are seen in other arteries.

I have already described an arrangement of blood-vessels at the root of the cord when speaking of its method of growth, but something more must here be said on this point. When the nozzle of the syringe is tied into the still attached cord an inch or two from the fœtal insertion, with the stream towards the fœtus, the injection is made to travel with some difficulty, and it is always found to terminate in a sort of cone outside the blood-vessel, the apex of which is just within the dermal ring (Plate 12. fig. 13). At this point it seems impossible to get the injection to travel round the blood-vessel as it does elsewhere in the cord—that is, I have failed to get it to enter the subcutaneous tissue on the other side of the omphalic ring; and, as will be seen in the same specimen, I have been equally unable to get it to travel from the subcutaneous tissue into the substance of the cord even under so great a pressure as 500 millims.

When the extreme apex of the cone obtained by injecting the substance of the cord near the ring is examined by sufficient power, it will be seen that the injected canals (Plate 12. fig. 14) run up to and border immediately upon the nucleated fibrous and muscular tissue which constitutes the omphalic ring. I have failed to inject any capillaries from the tissue in this way.

It is clear, then, that there must be some special arrangement for the nutritive supply of the substance of the cord, as it does not obtain any assistance from the umbilical vessels; and mere stomatic absorption, though I think it undoubtedly plays a most important part in the nutrition of the cord, could hardly be considered as sufficient to do the whole work.

When the capillary plexus running from the dermal ring (already described) has been successfully injected, I have found that a peculiar vascular arrangement is also displayed in the centre of the cord, lying in the firm nucleated tissue which forms the omphalic ring, and to which is due unquestionably not only the process of growth of the cord, but also in great measure its nutrition and the processes of closure of the vessels of the ring, and the removal of the stump by inflammatory ulceration.

The basis of this arrangement is a peculiar sacculated sinus, a mere excavation in the fibrous tissue, as I have been quite unable to demonstrate any definite wall for it. It seems to have a spiral arrangement; for in section (Plate 13. fig. 15) it appears and disappears as only a screw

could. It extends from the omphalic ring at least 12 millims. up into the true substance of the cord, giving off at short intervals thick trunks which rapidly break up into capillaries. Nowhere in this peculiar vascular arrangement of the cord, either central or superficial, have I seen the capillaries turn up in loops as if to go back. They open, as I have seen in innumerable instances, directly into the canalicular system; and it is possible to inject a large extent of all these districts of the substance of the cord by placing a nozzle in the vein and first injecting the fœtus. After that has been accomplished, the capillaries, and finally the canalicular tissue of the cord, can be seen filling. In one section (Plate 13. fig. 15) the capillaries were seen opening into a limited district of the canalicular tissue, which evidently was somewhere near the apex of its cone.

The injected tissue was in immediate relation to the walls of an artery and of a vein. I believe that under favourable circumstances I may yet succeed in this way in injecting the whole substance of the cord.

The point of origin of this sinus I have as yet failed to work out; but I conclude it comes from the intercosto-lumbar arteries, as the injection of the cord does not appear until the skin of the abdomen is perfectly blue.

The superficial layer of capillaries may also be seen entering the canalicular tissue of the cord. They lie immediately under the surface of the cord.

It is quite evident that the analogy between this capillary supply for the cord and the Haversian system of canals in bone is complete. The Haversian canals admit red corpuscles, but the stellate lacunæ admit only liquor sanguinis. So it is with this nutrient arrangement of the cord; and not only is the function of the stellate canals of the cord identical with that of the lacunæ and canaliculi of bone, but their anatomy is the same minus the deposit of the salts of lime which occupy the alveoli. In the cord the place of the salts of lime is occupied by water containing some organic compounds.

In one cord I found a capillary extending nearly an inch from the omphalic structures, and which, when its surrounding and concentric layers of nucleated canals were stained with hæmatoxylin, very closely resembled an Haversian system (Plate 13. fig. 16). This is probably the continuation of the central sinus, as it does not appear to have a definite wall, and it lay about the middle of the section.

As yet I have not been able to demonstrate this vascular mechanism in any but perfectly fresh and mature children, because the friction to be overcome in order to make the injection pass round the front walls of the abdomen is so great that it requires a greater pressure than the liver will stand in immature children, which generally have been dead some time before they are injected.

IV. *Its Vessels.*

In all previous descriptions it seems to have been taken for granted that the umbilical vein and arteries are identical with blood-vessels elsewhere; but I have already pointed out some important differences, and I have now to describe some others.

When the arteries and vein of a cord which has been removed from a mature and living child are examined, the arteries are found contracted to a very small size, and the vein is also found to be much contracted. The introduction of a tapering probe into the canal of an artery or of a vein shows that it can be readily dilated; and the forcible distention of the whole tube with water may be made to enlarge the diameter of the tube as much as four or five times. In the vein the possible distention is even greater; but in both there is a limit to it, and the walls are so strong that they resist a pressure of 800 millims. The distention is quite equable, and never presents any sacculations.

The proper tissue of the vessel is made up of the ordinary fusiform fibre-cells with their characteristic rod-shaped oval nuclei, the external coat being, as I have already shown, the canalicular tissue of the district proper to each blood-vessel. To the arteries there is certainly no inner or endothelial coat, though when the vessel is contracted, the inner fibres being pressed into folds by the contractions of the outer layers, their nuclei present at the apex of the fold a very deceptive appearance (Plate 14. fig. 25). Staining with silver or hæmatoxylin, however, gives the most decided indications of the absence of endothelium in the arteries, but in the vein it is probably present.

When a section is made of a fresh cord, removed from a mature and living child, in which one artery has been distended and the other left untouched, it will be seen that the contraction produces an arrangement of folds somewhat resembling what takes place in the closure of the œsophagus. The inner layers contract; but the outer layers seem to contract still more, so that the internal fibres become bent on themselves and form rugose prominences, which almost meet in the middle of the lumen of the tube (Plate 13. fig. 20) In the vein the muscular wall is much thinner, and this folding of the inner walls is not seen.

This does not take place in any other artery which I have examined for the purpose; at least, if it does so it becomes undone after death; but I did not find it in the carotid of a guineapig divided and examined immediately after death.

This extraordinary power of contraction of the umbilical artery is due to three conditions—the exceptional thickness of the muscular layer, the absence of any restraint by a firm external or any internal coat, and a peculiar arrangement of the external bundles of muscular fibres.

In the distended artery, examined after the addition of acetic acid, or after treatment by hæmatoxylin or silver lactate, the rod-shaped nuclei are seen to lie all in parallel directions, which are concentric with the

lumen of the tube. In the contracted artery it is different. The fibres are seen distinctly to be arranged in bundles, and these bundles have different directions. Some are seen to be cut across, whilst others can be traced passing downwards through the section and ending on the lower surface. When a very thin section is made, stained, dried on the slide, and mounted in balsam or dammar, here and there two layers of bundles are seen, one immediately above the other, crossing one another like the limbs of St. Andrew's cross. Again, two sets of bundles may seem to be arranged like the webs on the shaft of a feather; longitudinal sections show this still better. Prolonged exposure to the action of acetic acid shows, in a longitudinal section of an artery, that the muscular fibres are arranged in bundles, the directions of which occupy a double spiral (Plate 13. fig. 17), somewhat like that carefully described by Dr. Bell Pettigrew as being the arrangement of the fibres of the heart. Silver-staining also demonstrates this. I have made a diagram of this arrangement (Plate 13. fig. 18), and it may be fairly well illustrated by the way in which a ball of twine is cast on the spindle. If the hole through which the spindle has been passed be supposed to represent the lumen of the artery, a distention of that aperture would, if the string were elastic as the fusiform fibres are, drag the string into a uniform direction concentric with the hole. There can be no doubt that such an arrangement, especially in the external bundles, where it seems to be most marked, would be of great mechanical advantage in the closure of the vessels.

One makroscopic fact is certainly in support of this view, which is that the length of an artery in the umbilical cord is very perceptibly diminished after its distention.

It remains a very interesting point to consider whether this spiral arrangement will not be found to exist in other arteries as well as in those of the umbilical cord. Dr. Beale figures it as occurring in the longitudinal fibres of the aorta of the horse.

In support of my statement that there is no endothelium in the arteries of the cord I may detail the following observations.

In the case of the vein silver-staining reveals no difference in the arrangement of the inner surface before and after distention with air, and the appearances are very much the same as is seen in the endothelium of other vessels. But in the arteries, if the inner surface be silver-stained before distention, the brown lines will be found to include long fusiform spaces very different from those seen enclosing endothelium elsewhere (Plate 14. fig. 25); and if the same artery be distended with air and then stained, the fine brown lines will be found to be replaced by thick and much less regular brown interspaces (Plate 14. fig. 26). There, it appears to me, the fusiform cells are elongated to their utmost and somewhat separated; and the appearances are inconsistent with my experience of vessels elsewhere lined with endothelium, and they are quite consistent with the appearances noted after the treatment of trans-

verse sections of the umbilical arteries, distended and undistended, with vegetable-colour stains.

I have already stated that I have failed to find any trace of nerve-fibres in any part of the cord. By what mechanism, then, can this process of contraction be set going? It seems to me that the answer is readily found in three facts. First, there is no endothelium in the umbilical arteries, and the muscular fibres are therefore directly in contact with the blood which flows in them, that blood being venous as long as the placental circulation continues *. Second, it has now been well established, by Dr. Richard Norris and others, that contractility exists in muscle itself, and that nerve-influence is only its regulator, its exciter, or even its controller. Muscles depend most for their contractility on the contact of arterial blood. Thirdly, in the infant this happens to the muscular fibre of the umbilical arteries with the first few respirations. The blood in them up till that time has been venous, and suddenly becoming arterial, it throws them into violent contraction. By the cessation of the supply of arterial blood they may again dilate; for Simpson, in his collected memoirs (posthumous edition, vol. i. p. 228), says, "It is generally acknowledged by physiologists, as the result of various observations, that immediately after the child is born the umbilical vessels cease to pulsate and carry blood if the pulmonary respiration becomes active, and if the pulmonary respiration is by any cause interrupted or arrested before the cord is divided, the circulation through the umbilical vessels again becomes more or less active. Hence various practitioners have gone so far as to aver that it is unnecessary, as a general rule, to place a ligature upon the fœtal extremity of the cut umbilical cord if the cord be not cut till the child has cried loudly."

This I have repeatedly verified by experiment. By refraining from dividing the cord for a few minutes after the child is born, some very interesting observations can be made. If the child do not cry at once, and the placenta be left *in situ*, the arteries of the cord may be felt to pulsate strongly. If the child cries freely, they at once cease to beat and contract to firm threads, being felt through the flabby cord almost like cartilage. Should the child's respiration cease for a few moments they again relax and pulsate, and contract once more when the child cries. When the possibility of the circulation through the cord is arrested by the application of a ligature its stump soon ceases to give any indication of pulsation, because only arterial blood can then pass into it. The contraction and subsequent obliteration of the hypogastric arteries take place

* The arterialization of the blood in the capillaries, especially of the central veins of the cord, may also have much to do in exciting the contraction of the arterial coats. It may also be from this central sinus that this peculiar form of hæmorrhage occurs, which is sometimes seen after the separation of the stump.

This hæmorrhage is passive but arterial, and is seldom controlled by any ordinary hæmostatic agency. The absence of muscular walls from this sinus seems to explain some of the facts of this hæmorrhage.

in exactly similar ways; indeed my observations were first made in these arteries and were subsequently extended to the cord.

The permanent closure of these vessels and of the stump of the cord is accomplished partially by clot, but chiefly by the aid of the round wandering cells previously described. They also play a very important part in what is an extremely common cause of premature death and expulsion of the fœtus. My conclusions are based upon the examination of the omphalic structures of several children who have died within thirty-six hours after birth, but chiefly on two cases of omphalic thrombosis.

It seems that immediately the arteries of the cord have contracted and the inner layers have been pressed into the folds already described (Plate 13. fig. 20), the remaining interval is filled with blood which coagulates. In the stump of a cord which had belonged to a child which lived only a few hours, I found the tissue of all the vessels permeated with the large round nucleated cells, and a few had even entered the mass of blood-corpuscles. Where the clot was not present these cells seemed to become adherent by a granular blastema to the inner surface of the wall, and to tend to arrange themselves in processes on the apices of the folds (Plate 14. fig. 22). It is doubtless through the agency of these cells mainly that the vessels are closed. I have seen complete closure without any trace of a clot; and in such a case these cells alone must effect the process. In a case where the child had lived about two days, and the cord was partly desiccated, the internal layer of muscular fibres of the arteries had in great part disappeared, leaving lacunar spaces, which were occupied by the large cells, and a complete layer of them existed between the muscular coat and the clot.

This was more and more evident as the sections neared the child. The appearances of this retrograde change (Plate 14. fig. 23) at some parts of this cord were so curious as to become almost suggestive that the muscular fibre and the nucleated canalicular tissue are developed from the same cells, that they are a mere modification of the same tissue. Some of the cells mentioned as lying in the retrograde lacunæ of the inner layer of the muscular fibres of the artery possessed the same peculiar small nucleolus as is seen in the nuclei of the canals. These cells are also seen apparently passing through amongst the outer layers of the arterial coat.

In a case where a dead child was expelled at the eighth month, clots were found to occupy the arteries from the base of the bladder to within a short distance of the cord; and in this cord (Plate 12. fig. 9) the round cells were abundant throughout the cord, and were especially numerous in the meshes of the muscular tissues of the arteries. Round the clot was a complete ring of these cells, apparently intimately associated with it; and a few of the cells could even be seen isolated among the blood-corpuscles, though this appearance may be due merely to their

dislodgement during the process of preparation of the section (Plate 12. fig. 11).

Further proofs that these wandering cells are very efficient in the various processes of the cord and an indication of the source of their origin are obtained by the examination of the cords in cases of extra-uterine gestation. I have operated in two such cases, removing children which were quite fresh, one having been dead probably from six to ten days, and the other about three months. In both cases the cords were unaltered, save that in the second it seemed to be somewhat shrivelled. In the first case it was full and plump; but the vessels were uncontracted and unclosed, and there were no indications of any wandering cells anywhere, though the canalicular nuclei were easily displayed. The appearances in the second were somewhat similar, with the addition that the canalicular tissue was contracted, just as it becomes when the cord is examined after maceration in some hardening fluid. The canalicular nuclei were not easily shown, and appeared only here and there.

In such displacement the child seems to die of asphyxia, from the closure of some part of the canals of the mechanism by which the blood is oxygenated, and which will probably be found to occur in the placenta. The fœtal circulation ceasing, we have an arrest of the production of the wandering cells by the omphalic capillaries; and consequently they are absent from the tissue of the cord, and there is no attempt to close the vessels.

The fact that thrombosis of the arteries occurs at least eight times more frequently than thrombosis of the vein*, and that the clots are always adherent to the walls of the arteries and more firmly than to the walls of the vein, seems also to point to this conclusion.

V. *Its Relations to the Fœtus and Placenta.*

The relations of the cord to the fœtus and placenta are very interesting. The fœtal attachment of the cord has already been described at some length when speaking of the vascular supply to the canalicular tissue. In the omphalic ring nothing of the cord is found but the muscular substance of the three vessels which pass inwards, the arteries towards the pelvis, and the vein on its passage to the liver.

The canalicular tissue ends in three of the cone-like processes already described, and into which the capillaries open, either from the superficial layer or from the central sinus, or from both.

The limitation of the canalicular tissue of the cord at its placental attachment is quite as abrupt.

When the nozzle of the syringe is inserted into one of the columns of the cord a short distance from the placenta and directed towards it, a ligature being placed tightly round the cord and nozzle to prevent regur-

* Steiner's 'Kinderkrankheiten,' 1873.

gitation, it will be found impossible to force the fluid into the substance of the placenta. It is limited by a membrane, derived from the inner layer of the chorion, into which the arteries pass to be included between two layers of it, and from between which two layers the veins emerge. This membrane is very tough; and if extreme pressure be used the fluid will be found to pass under the ligature and down the column which is being injected, or by rupture into one of the other columns, but never, according to my experiments, can it be made to pass through that membrane. There is absolutely no connexion, therefore, between the nutritive system of the cord and that of the placenta.

The amnion is loosely attached over the placenta by some cellular tissue, which Arthur Farre describes as the *tunica media*. But the amnion becomes adherent to the cord a few lines on the fœtal side of the basis membrane of the placenta.

The relations of this attachment have yet to be made out.

VI. *Its Nutrition.*

From what I have already said it will be apparent that I regard the chief factor in the nutrition of the cord to be the capillary arrangements at its fœtal insertion, at which point the cord grows and obtains its spiral form, and from which also it derives its supply of wandering cells. From the facts observed in cases of extra-uterine gestation, however, it has seemed to me to be likely that the stomata on the epithelial surface of the cord also play an important part in its nutrition. The liquor amnii contains casein, creatin, lactic acid, grape-sugar, and some saline matter, all of which are very suggestive that the fluid is used for the purposes of nutrition, and perhaps for that of the cord. In recent cases of extra-uterine fœtation, before the liquor amnii becomes absorbed, the cord remains fresh and plump. After the liquor amnii has become absorbed it becomes shrivelled, but still retains its structural character minus the wandering cells. It may be, therefore, that the canalicular nuclei may be able to keep the cord in repair, as it were, by the matters absorbed from the liquor amnii, until that fluid disappears, very much as ivy continues to live after its connexion with the root has been severed. Indeed the resemblance between the umbilical cord and vegetable tissue is a very close one, as I have previously indicated, and as I may in future communications be able to make still more clear.

Appendix.—Received June 14, 1875.

Since the preceding note was written, I have been able completely to verify Virchow's depiction of the arrangement of capillaries on the surface of the cord, in continuity with those of the dermal ring.

The existence of this arrangement, however, must be exceptional, and

is probably only an early stage of the more perfect plan already described, for I have only found it in this one case.

The fœtus in which the observation was made was a large one, but not fully developed, having probably not reached within six weeks of maturity. The injection was very successful, and was made under a pressure of only 100 millims., and the plexus of vessels was seen to extend about 5 millims. over the venous surface of the cord (Plate 13. fig. 21, *b*). But on examining the vessels with a power of thirty diameters, it is readily seen that these capillaries did not return in loops, but seemed to be lost in the substance of the cord—contrasting in this relation very markedly with the capillaries of the dermal ring, from a large trunk of which they arose. These latter are arranged in loops for the return of the circulation, as is the case with capillaries almost everywhere else; but those in the cord have an arrangement more like that of the branches of a tree. Further, it is noticeable that the capillaries spreading over the surface of the cord may be seen to arise by the aggregation of smaller roots, just as I have pointed out to be the case in the formation of the central sinus of the cord (Plate 13. fig. 21, *a*).

None of the canalicular tissue of the cord could be seen to have been injected from these capillaries; but the pressure used was too low to accomplish that, as the injection had to be made for another purpose.

The umbilical cord in this case had been cut off about 60 millims. from the dermal ring, and the injection as usual was made from the vein.

On making a section of the cord immediately below the ligature which retained the injecting nozzle, a small spot of injection was seen in the substance of the cord lying close outside the wall of the vein. This was found to be the central sinus of the cord; and on being carefully traced towards the fœtus, it was found to curve spirally close alongside the vein and to enter and pass through the omphalic canal in the midst of the three vessels.

Throughout its course, examination by a power of thirty diameters showed that it gave off branches which rapidly broke up and were lost in the tissue of the cord.

Finally, it was found to arise from several small branches, four of which at least are preserved and are represented in the drawing (Plate 13. fig. 19). They arose from the lower intercostal arteries, and gathering together on the lower surface of the omphalic vein, combined in the omphalic canal to form the sinus.

From this case it is evident that this sinus at least occasionally passes very far into the cord, as the point where it was discovered was at least 45 millims. from the dermal ring.

(I think it is possible that the radicles of this sinus may be what Kölliker described as the nerve-twigs derived from the hepatic plexus.)

EXPLANATION OF THE PLATES.

Plate 11.

Fig. 1. Median section of cord, showing the dermal ring to extend further on the cord on the upper or venous side than on the lower (actual size).
Fig. 2. Surface of cord and dermal ring, dissected off and laid flat, showing the capillaries of the former and the camb-like projection of the latter (actual size).
Fig. 3. Surface of cord, silver-stained, and epithelium partly removed ($\times$ 1000).
Fig. 4. Transverse section of cord, showing one of its three columns injected ($\times$ 120).
Fig. 5. Canalicular tissue of cord, injected ($\times$ 250).
Fig. 6. Ditto, with nuclei stained ($\times$ 200).
Fig. 7. Nuclei of canalicular tissue, highly magnified ($\times$ 1000).
Fig. 8. Ditto, with canals uninjected ($\times$ 250).

Plate 12.

Fig. 9. Round wandering cells in alveoli ($\times$700).
Fig. 10. Round cells, highly magnified ($\times$ 1000).
Fig. 11. Ditto in neighbourhood of capillary, and some invading the blood-clot ($\times$ 1000).
Fig. 12. Two umbilical arteries, with central sinus of cord lying near them ($\times$ 20).
Fig. 13. Median section of cord and omphalic structures, with canalicular tissue (at arrow) injected on the one side of the ring, and on the other the subcutaneous tissue injected (actual size).
Fig. 14. Terminal cone of canalicular tissue, injected ($\times$ 120).

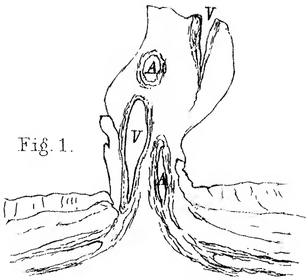
Plate 13.

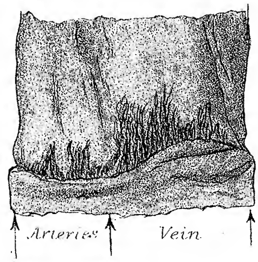
Fig. 15. Central sinus of cord, with its branches and canalicular tissue injected from them ($\times$ 20).
Fig. 16. Capillary of cord, one inch from dermal ring, showing its relations to the lacunar spaces and resemblance to Haversian system ($\times$ 200).
Fig. 17. Two layers of the external coat of an umbilical artery ($\times$ 200).
Fig. 18. Diagram of the same.
Fig. 19. Drawing of roots of origin and course of central sinus of cord (by Mr. Priestley Smith, actual size).
Fig. 20. Transverse section of umbilical artery, showing rugæ ($\times$ 20).
Fig. 21. Capillaries running on to the cord from the dermal ring: *a*, showing method of origin ($\times$ 3); *b*, actual size.

Plate 14.

Fig. 22. Arrangement of wandering cells on rugæ of contracted artery for closing it ($\times$ 1000).
Fig. 23. Retrograde change in muscular coats of arteries ($\times$ 1000).
Fig. 24. Endothelium of vein, silver-stained ($\times$ 1000).
Fig. 25. Inner surface of contracted artery, silver-stained ($\times$ 500).
Fig. 26. Inner surface of distended artery, silver-stained ($\times$ 500).

Fig. 1.





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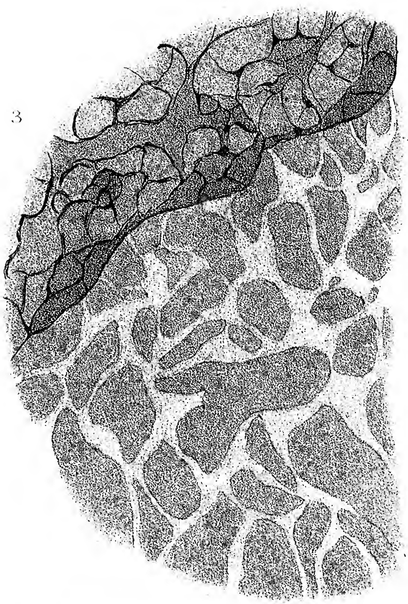

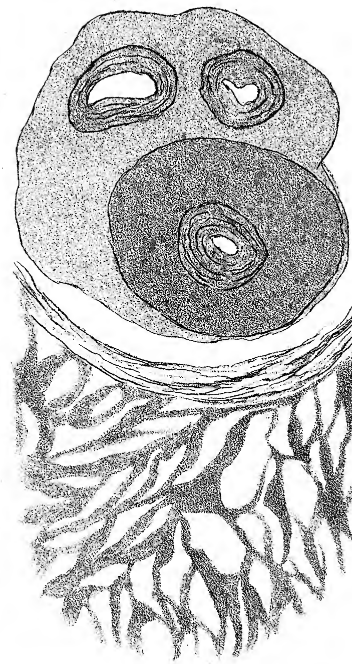

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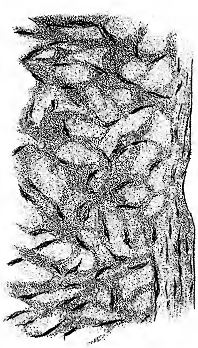

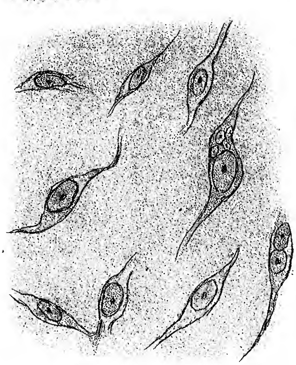

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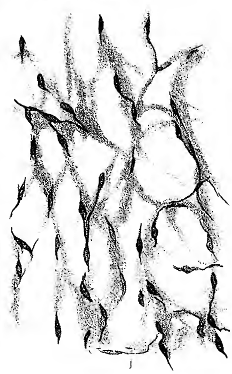

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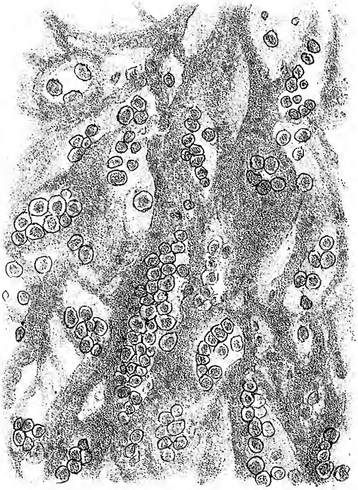
W.H. Wesley lith.

L. Tait delt.

W. West & C° imp.

9



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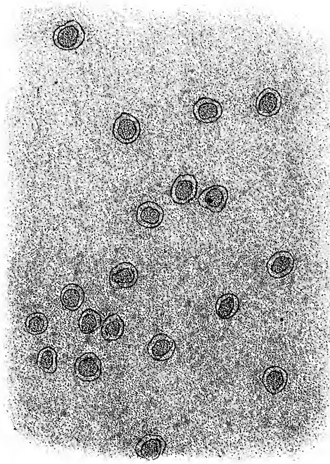

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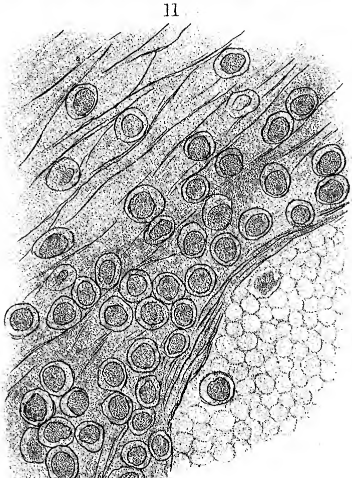

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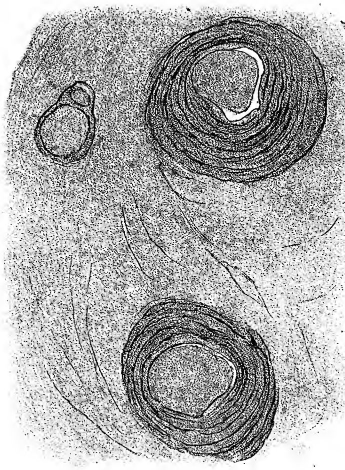

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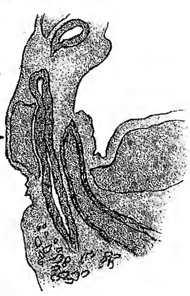

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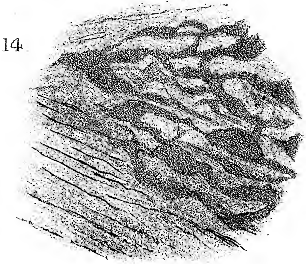

W.H. Wesley lith. L. Tait delt. W. West & C° imp.

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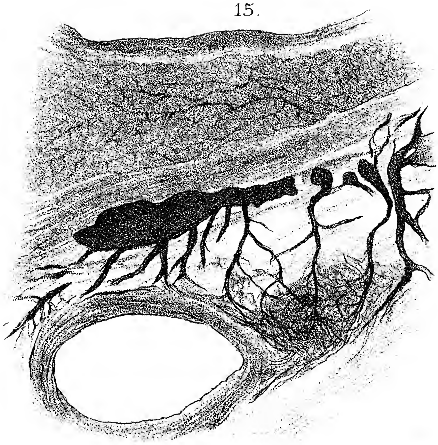

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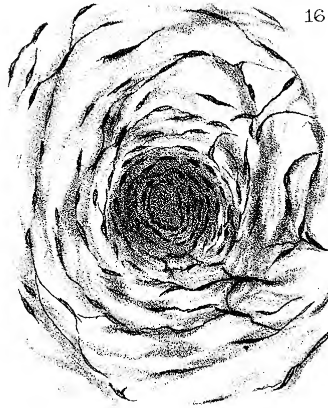

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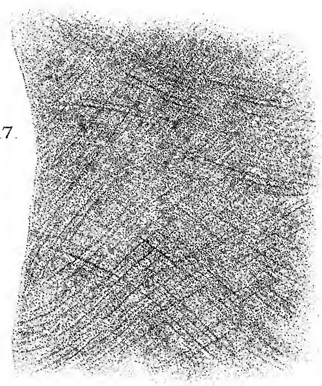

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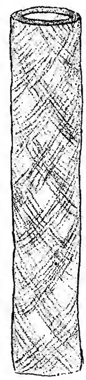

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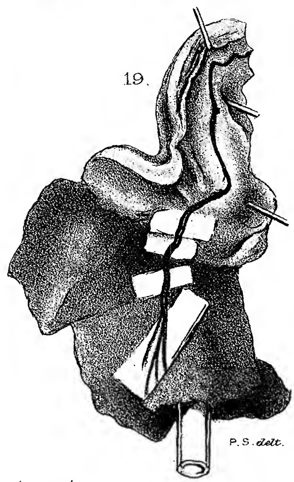

P. S. *delt.*

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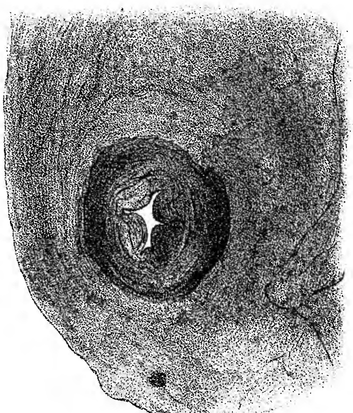

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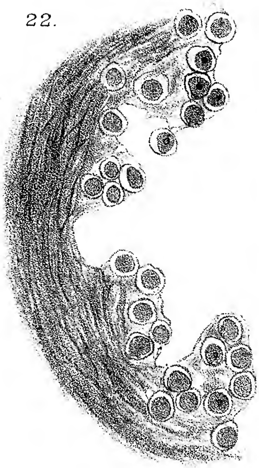

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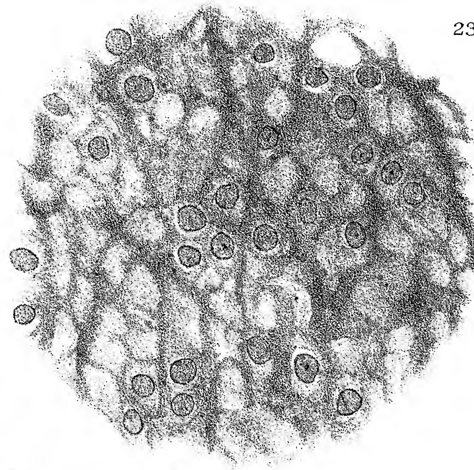

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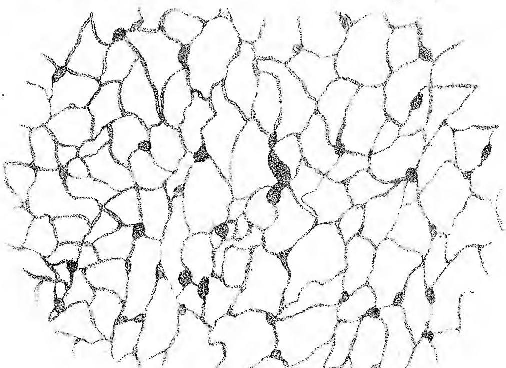

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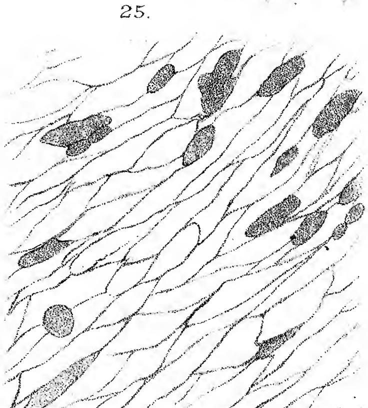

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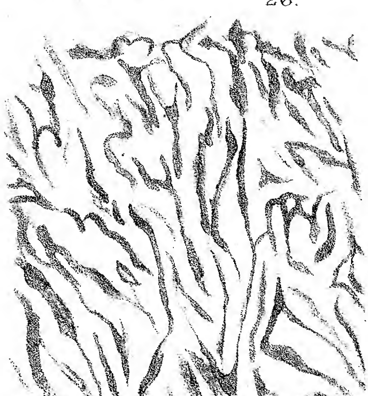
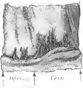
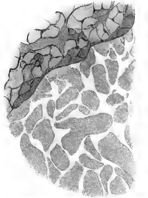
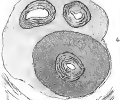


W. H. Wesley lith. L. Tait delt. W. West & C° imp.

Fig. 1







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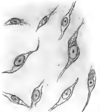

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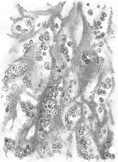

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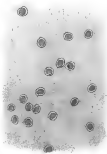

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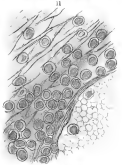

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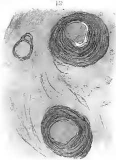

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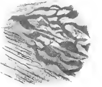

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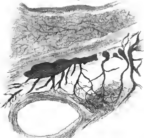

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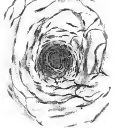

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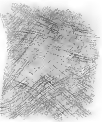

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P S delt

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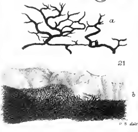

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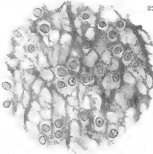

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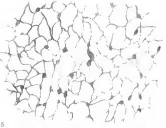

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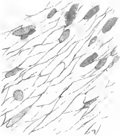

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